Sounding Rocket Systems Engineering Mission Design: From Concept to Proposal

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1. Abstract

The goal of this internship was to develop a proposal for the VISIONS-3 sounding rocket mission, and to understand the mission proposal process. The results of this project are a trajectory and launch vehicle selection, defined mass and monetary budgets, mechanical sizing of the payload, data simulation, and a science traceability matrix.

2. VISIONS and VISIONS-2 Mission Objective

The primary mission of the VISIONS and VISIONS-2 rockets are to determine how, when, and where ions are accelerated to escape velocities in the auroral zone and cusp below 1000km [1]. VISIONS-1 used one sounding rocket, and VISIONS-2 used two launched along the same trajectory. VISIONS-3 will use two sounding rockets launched on different trajectories to use topographical reconstruction, graphically displayed in figure 2.

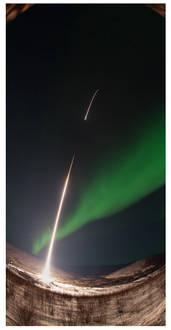

Figure 1: Sounding rocket launched into aurora [2]

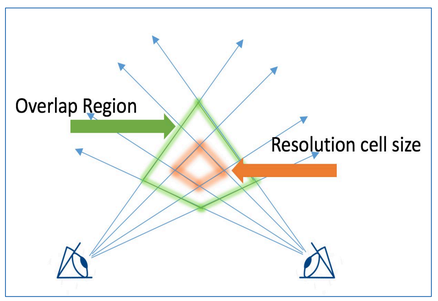

Figure 2: Diagram detailing benefits of tomographic reconstruction. Having two "viewers" (in this case, sounding rockets) allows for an overlap of line-of-sight regions, which provides a boundary condition to mathematically constrain the data analysis.

3. Why Sounding Rockets?

1. Much less expensive than larger launch vehicles; can be launched more often.
2. Allows testing of components in zero-gravity; can be tested and improved for larger and longer missions.
3. Average life span of mission is shorter than larger missions; allows exposure to entire mission cycle.

4. Tasks Completed

Completing the tasks listed below is a circular process, since each aspect is dependent on the rest. The flow chart displays the chronological order which tasks were completed for this internship.

Select Trajectory

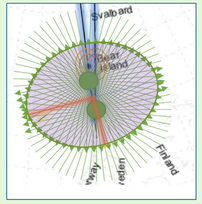

Figure 3: Overlap region shaded in purple of two sounding rockets. The red lines are approximate semi-major and minor axes of the ellipse. The area of this region determines where data can be collected.

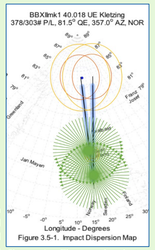

Figure 4-1. Impact Dispersion Map

Figure 4: The spacing between the circles displays a time difference between launches. Time delays of 1-5 minutes were investigated.

Select Launch

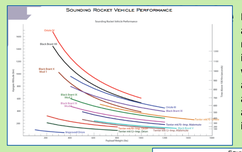

Figure 5: Performance aspects of each sounding rocket were analyzed, including apogee reached with a payload mass. Using a payload mass estimate, and knowing a desired altitude range of >650km, influenced the decision [3].

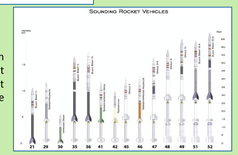

Figure 6: Illustrations of each sounding rocket. The height and mass of each rocket determines how high the rocket can fly [3].

Mechanical Sizing

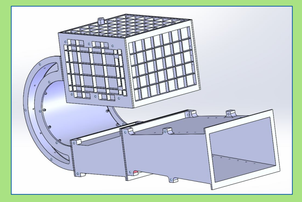

Figure 7: Mechanical CAD model of the Experimental Energized Neutral Atom (E-ENA) Imager instrument. Energized neutral atoms enter the duct on the bottom right and pass through a series of magnets and filters before being imaged. The instrument was too large to fit in the original payload size, so a different orientation and rocket skin were needed to include the desired result.

Create Mass Budget

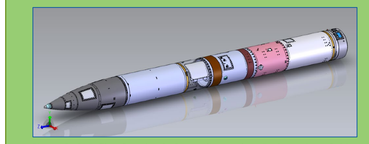

Figure 8: CAD file of payload of sounding rocket. Each section of this payload has a defined mass that combined with the number of E-ENA instruments, creates the total mass.

TM: Weight = 125.29 lbs, CG = 16.06"
ACS: Weight = 80.62 lbs (88.62 w/ gas), CG = 9.92" (10.17" w/ gas)
E-ENA: Weight = 100.08 lbs, CG = 15.43"
BBXII Motor Adapter and CDI: Weight = 43.0 lbs, CG = 2.95"

Figure 9: Masses and specifications for each component of the sounding rocket, received from Mike Tolbert.

Monetary Budget

Instruments and Scientific Support		
First E-ENA Instrument	Subsequent E-ENA Instruments	People
~600k	~200k	~200k/year

Figure 10: Estimated budget for scientific instruments. The sounding rocket itself does not need to be paid for since it is provided through NASA Wallops – thus, the main goal of this budget is to maximize the number of E-ENA instruments to increase the field of view for scientific measurements.

Science Traceability Matrix

Instrument	Measurement Parameters	Science Data Products	Detailed Science Question Addressed	Data Analysis Method
E-ENA (Experimental Energized Neutral Atoms Imager) **(GSFC)** Note: There will be multiple E-ENA's	Apogee above 650km Rocket spinning with a 2 second period Launch into poleward moving aurora form (PWMAF) Angular resolution: 6°x6° Energy range 10 eV to 3 keV	Time History of ENA fluxes vs. energy 4-D reconstruction of parent ions (with modeling)	What are the spatial and temporal variations of >10eV ion outflow in the cusp?	2 vehicle tomographic reconstruction

Figure 11: The Science Traceability Matrix details the relationship between all main instruments and compares the different aspects of the instrument and their effect on the outcome of the mission.

Tasks to be Completed

Science Question

Overarching goal of mission; leads to hypothesis of mission, details what mission is intended to accomplish and what scientific answers are sought.

Data Simulation

Goals: Model overlap region and topographical reconstruction in 3D.

Instrument Accommodation Requirements

Interface description of all components.

Write Proposal

5. Conclusions

1. Trajectory Selection: To be launched from Norway, 3 minutes apart.
2. Launch Vehicle: Use a Black Brant XII with a 25 inch bulbous payload.
3. Mechanical Sizing: Mount E-ENA's sideways within bulbous payload, use 4-6 instruments.
4. Mass Budget: Mass is within parameters to reach desired altitude. May change as process continues.
5. Monetary Budget: Remain underneath 2 million.

6. Why is this important?

Most communications and scientific satellites in orbit around Earth are in the region that radiation from space weather can damage their electronics – improved shielding can result from better understanding space weather. Insight into our ionosphere, magnetosphere, ion outflow, and the "boiling off" phenomenon of our atmosphere may provide understanding of how the atmosphere of other planets (e.g. Mars) disappeared. This would provide further insight into the life cycle of planets and atmospheres. Additionally, a heightened understanding of space physics could lead to the ability to predict which exoplanets may have an atmosphere and magnetic field like Earth using deep space telescopes.

7. Future Work

1. Data Simulation: to be created in either MATLAB or similar software; create 3D model to display results similar to those created in 2D in Figure 3.
2. Complete Science Question and Instrument Accommodation Requirements.
3. Write proposal to submit to NASA.

Acknowledgments

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References

[1] Rowland, Douglas. Reconstruction of auroral zone ion outflow during a substorm from VISIONS ENA measurements. Retrieved July 27, 2017.
[2] Sounding Rocket[Digital image]. (n.d.). Retrieved July 23, 2018, from https://www.nasa.gov/sites/default/files/styles/full_width/public/img_6561_1.jpg?itok=czRca_jt
[3] Sounding Rockets [Digital Image]. (n.d.). Retrieved July 23 2018 from https://sites.wff.nasa.gov/code810/files/Sounding%20Rockets%20Annual%20Report%202017.pdf